

Dawn maps the surface composition of Vesta

T. Prettyman (1), H. McSween (2), M. C. De Sanctis (3), E. Ammannito (4), D. Blewett (5), B. Buratti (6), F. Capaccioni (3), M. T. Capria (3), F. Carraro (4), J. P. Combe (7), A. Coradini (4), B. Denevi (5), W. Feldman (1), G. Filacchione (3), S. Fonte (4), O. Forni (8), M. Gaffey (9), B. Garry (1), H. Hiesinger (10), R. Jaumann (11), U. Keller (12), D. Lawrence (5), L. Le Corre (13), J.-L. Li (14), G. Magni (3), S. Marchi (15), T. Maue (16), T. McCord (7), T. McCoy (17), L. McFadden (18), D. Mittlefehldt (19), A. Nathues (16), G. Neukum (20), R. Noschese (4), E. Palmer (1), C. Pieters (21), C. A. Raymond (6), R. Reedy (1), V. Reddy (9), C. T. Russell (22), J. Scully (22), J. Sunshine (14), M. Sykes (1), T. Titus (23), M. Toplis (24), F. Tosi (4), P. Tricarico (1), R. Yingst (1), M. Zuber (25)

(1) Planetary Science Institute, Tucson, AZ, USA, (2) University of Tennessee, Knoxville, TN, USA, (3) INAF/Istituto di Astrofisica Spaziale e Fisica Cosmica, Rome, Italy, (4) INAF/Istituto di Fisica dello Spazio Interplanetario, Rome, Italy, (5) Applied Physics Laboratory, Johns Hopkins University, Baltimore, MD, USA, (6) Jet Propulsion Laboratory, Pasadena, CA, USA, (7) Bear Fight Institute, Winthrop, WA, USA, (8) Centre d'Etude Spatiale des Rayonnements, France (9) University of North Dakota, Grand Forks, ND, USA, (10) University of Muenster, Germany, (11) DLR Institute for Planetary Research, Berlin, Germany, (12) University of Braunschweig, Germany, (13) Laboratoire de Planétologie et Géodynamique, France, (14) University of Maryland, College Park, MD, USA, (15) L'Observatoire de la Côte d'Azur, France, (16) Max Planck Institute for Solar System Research, Katlenburg-Lindau, Germany, (17) Smithsonian Institution, Washington, DC, USA, (18) NASA Goddard Spaceflight Center, Greenbelt, MD, USA, (19) NASA Johnson Space Center, Houston, TX, USA, (20) Freie University of Berlin, Germany, (21) Brown University, Providence, RI, USA, (22) University of California, Los Angeles, CA, USA, (23) US Geological Survey, Flagstaff, AZ, USA, (24) University of Toulouse, France, (25) Massachusetts Institute of Technology, Cambridge, MA, USA.

Abstract

By 7-October-2011, the Dawn mission will have completed Survey orbit and commenced high altitude mapping of 4Vesta. We present a preliminary analysis of data acquired by Dawn's Framing Camera (FC) and the Visual and InfraRed Spectrometer (VIR) to map mineralogy and surface temperature, and to detect and quantify surficial OH. The radiometric calibration of VIR and FC is described. Background counting data acquired by GRaND are used to determine elemental detection limits from measurements at low altitude, which will commence in November. Geochemical models used in the interpretation of the data are described. Thermal properties, mineral-, and geochemical-data are combined to provide constraints on Vesta's formation and thermal evolution, the delivery of exogenic materials, space weathering processes, and the origin of the howardite, eucrite, and diogenite (HED) meteorites.

1. Introduction

In July of 2011, the Dawn spacecraft will rendezvous with 4Vesta, an asteroid that underwent igneous differentiation and is thought to be the source of the HED meteorites. Dawn will spend roughly a year in Vesta orbit studying its surface and gravity field to determine its geologic history and to establish its relationship with the HEDs. Dawn's three payload

instruments, FC [1], VIR [2], and GRaND [3], are sensitive to the composition of Vesta's surface. The instruments are complementary (FC and VIR are sensitive to mineral composition and GRaND is sensitive to elemental composition). Some themes addressed by the measurement of surface composition include [1-5]:

- Reconstruction of Vesta's thermal evolution (did Vesta have a magma ocean?);
- Geochemistry, mineralogy and chronology of Vesta's surface in relation to the HED meteorites to other differentiated bodies (Vestoids);
- Interpretation of processes that formed crustal terranes and outcrops of the mantle and deep crust, which may be exposed in the large south polar impact basin;
- Nature of the regolith, including thermophysical properties, proportions of petrologic components, space weathering, exotic materials, and the form and content of H.

Compositional data will be acquired at disparate spatial scales and at different phases of operations at Vesta. Early results are anticipated for FC and VIR. In Survey orbit (3000 km radial distance), FC will map color variations at high resolution (with nearly full coverage of Vesta on scales of about 200 m/pixel). VIR will map spectral variations for

visible and IR wavelengths, providing measurements of the abundance of pyroxene, olivine, surface temperature, and constraints of surficial OH, all on spatial scales smaller than 700 m/pixel in Survey. The radiometric calibration of VIR in the visible range is strengthened by intercalibration with FC, which observed Mars during Mars Gravity Assist. Additional data will be acquired by FC and VIR in a high altitude mapping orbit (HAMO) at 900 km orbital radius and also in a low altitude mapping orbit (LAMO). Before departure, FC and VIR will map the northern high latitudes of Vesta under favorable illumination conditions, providing full coverage of Vesta.

GRaND will accumulate global counting data while Dawn is in LAMO, for about 70 days at an orbital radius of about 460 km. The counting data will be analyzed to map elemental abundances on coarse spatial scales (about 300 km/pixel). GRaND will determine the abundance of major rock forming elements (such as Mg, Si, and Fe), and trace elements H, K and Th. The K/Th ratio provides a measure of volatile depletion in the material that accreted to form Vesta, which can be compared to other solar system bodies. GRaND will also map the neutron absorption cross section and average atomic mass, providing bounds on the abundance of elements not detected in the gamma ray spectrum. The chemical information provided by GRaND will be used to determine mixing ratios for HED end members as well as normative mineral abundances.

2. Combined approach

Data from all three instruments will be combined to address the aforementioned science themes [e.g., 4]. For example, elemental abundances measured by GRaND will be mapped onto coarse compositional units defined by FC and VIR. Whereas VIR can measure pyroxene and olivine, GRaND can additionally constrain the proportions of plagioclase and mafic minerals. A striking difference between optical and nuclear techniques is depth sensitivity. FC and VIR are sensitive to depths of a few nanometers in the visible range. In contrast, GRaND is sensitive to depths of several decimeters. Differences in surface and bulk composition could aid in characterizing regolith processes. Independent measurements of OH by VIR and H by GRaND can be used to constrain sources of exogenic H (solar wind implantation vs. delivery by carbonaceous meteorites).

3. Meteoritic constraints

The mineralogical and geochemical compositions of HED meteorites have been used to construct mixing models for the interpretation of GRaND data [3,7] and will serve as ground truth for spectral interpretation. It should be possible to constrain the relative amounts of near-surface (eucrite) and plutonic (diogenite) components in the regolith, and to recognize possible deep crustal or mantle materials containing olivine.

4. Conclusion

Our present understanding of Vesta is based on telescopic remote sensing and the analysis of the HED meteorites, which are thought to be representative of Vesta as a whole. What surprises might be in store when Dawn arrives at Vesta? The composition of materials exposed on the asteroid's surface will provide new insights into the processes that produced the solar system's largest differentiated asteroid.

Acknowledgements

This work was carried out under the auspices of the National Aeronautics and Space Administration by the Dawn Science Team under contract NNM05AA86C.

References

- [1] Sierks H. et al.: The Dawn Framing Camera, submitted to Space Sci Rev (2011).
- [2] De Sanctis, M. C. et al.: The VIR Spectrometer, Space Sci Rev (2011) DOI 10.1007/s11214-010-9668-5.
- [3] Prettyman, T. et al.: Dawn's Gamma Ray and Neutron Detector, submitted to Space Sci Rev (2011).
- [4] Pieters, C. et al.: Surface composition of Vesta: Issues and integrated approach, submitted to Space Sci Rev (2011).
- [5] McSween, H. et al.: HED Meteorites and Their Relationship to the Geology of Vesta and the Dawn Mission, Space Sci Rev (2011) DOI 10.1007/s11214-010-9637-z
- [6] McCord et al., this proceedings.
- [7] Usui, T. et al., K-Th-Ti systematics and new three-component mixing model of HED meteorites: Prospective study for interpretation of gamma-ray and neutron spectra for the Dawn mission, Meteor Planet Sci (2010) DOI: 10.1111/j.1945-5100.2010.01071.x